Letters to the Editor.

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Atmospheric Refraction.

THE proposition that "the course of a nearly horizontal ray of light in the lower part of the atmosphere is a circular arc having a radius of 14,900 geographical miles" has been stated by Mr. Mallock in a letter in NATURE of June 9, p. 456. Mr. Mallock states later on in the same communication that rays that are pointed a few degrees up or down will still be arcs of a circle of 14,900 miles radius.

It has been customary for many years in all survey departments to assume that the angle of refraction on a ray bears to the angle subtended at the centre of the earth a ratio denoted by k, which is called the "coefficient of refraction," assumed to be constant at a given point for all rays. It is easy to see from this that the ratio of the curvature of the ray—tacitly assumed to be circular—to the curvature of the earth is $2k$; and that if $2k=1$ a horizontal ray would circle the earth. According to Mr. Mallock's result, $2k=3960/14{,}900$, taking the earth's radius as 3960 miles, which leads to $k=0{\cdot}133$. Now this is *not* a value ordinarily met with in practice. In Clarke's "Geodesy" values of k derived from observations of the Ordnance Survey are given as 0·0809 for rays over water and 0·0750 for rays over land. These values are not far different from values obtained from other surveys.

Mr. Mallock's reasoning is based on the equation

$$v_h=v_0\left(1-a\frac{H-h}{h}\right).$$

When $h=0$ this becomes $v_0(1-0{\cdot}00029)$, or v_0/μ, where μ is the refractive index of air at standard pressure and temperature. While this is correct, it appears to me to be quite erroneous to consider the equation as giving the correct velocity at heights of a few thousand feet. It may not be incorrect to state for a limited range of height that the velocity varies as the height; but surely it is incorrect to deduce the factor of this variation from an assumed law which gives the velocity at height H (the height of the homogeneous atmosphere $=8{\cdot}3$ km.) equal to the velocity *in vacuo*?

If the refracted ray is circular and of the same radius of curvature for rays deviating several degrees from the horizontal, it would follow that the value of k at two considerably different levels would be the same. Now the refraction depends on $\mu-1$, which varies as the density of the air. It is manifest that k is smaller at a considerable height than at sea-level in the proportion of the densities at the two heights. The value of k varies not only with the height, but also with the angle of elevation of the ray. The most convenient plan so far evolved is to speak of the "coefficient of *horizontal* refraction," k_0, and to give values for this quantity at various heights. Under certain average conditions for a ray from A to B, points the heights of which are h_a and h_b, the refraction may be computed by using the coefficient of horizontal refraction appropriate to height $1/3(2h_a+h_b)$, while for the reverse ray $1/3(h_a+2h_b)$ should be used. The values of k_0, which follow from purely theoretical considerations if a temperature gradient of 3° F. per 1000 ft. be assumed, vary from 0·08 at sea-level to 0·05 at 19,000 ft. for temperatures and pressures 82°, 30 in., and 25°, 15 in., respectively. These values are found to account very well for refraction in numerous Indian observations.

Refraction is not, in general, constant throughout the twenty-four hours. It is usually smallest in the afternoon at about 3 p.m., and the minimum value then reached is approximately the same from day to day. On this account observations are often restricted to the hours between 2 and 4 p.m. It may easily happen that the refraction at 8 a.m. is double that at 2 p.m. The values of k given above refer to minimum refraction. Recent research has shown that the diurnal change is due mainly to the changes of temperature in the first 300 ft. of the atmosphere; in that region the form of the ray of light is by no means circular. Beyond a height of 300 ft. temperature changes in the air due to conduction practically disappear. For rays of light which remain most or all of their length within a distance of 300 ft. from the ground, highly anomalous values of k may, and generally do, exist. In such cases afternoon refraction is smaller than is indicated by values of k already given, and in some cases is zero, or even negative. Such rays require special consideration.

Results of a good many observations will be found in my "Formulæ for Atmospheric Refraction and their Application to Terrestrial Refraction and Geodesy" (Professional Paper 14, Survey of India, Dehra Dun, 1913); and a more recent article in "The Dictionary of Applied Physics" (Macmillan and Co.), now under publication, may also be consulted.

J. DE GRAAFF HUNTER.

Dehra Dun, United Provinces, India, July 13.

THE only points in Dr. Graaff Hunter's letter to which I need refer are (1) the objection raised against taking the refractive-index gradient for the lower levels of the atmosphere as being identical with that which would make $\mu=1$ at the height of the homogeneous atmosphere, and (2) the statement that "conduction" of heat extends to a height of 300 ft. above the ground.

With regard to (1), the pressure gradient near the ground, and the density and refractive-index gradients also, decrease linearly at such a rate that if the linear relation continues to hold, the pressure and density would be zero and the refractive-index unity at the height H, and this is the gradient which should be used in correction for refraction to such heights, as the linear relation is a sufficient representation of the facts. How far depends on the order of accuracy aimed at.

Temperature effects may make a difference of 1 or 2 per cent. per 1000 ft., but in such an uncertain correction as that for terrestrial refraction this is scarcely worth notice.

The presence of water-vapour will have an effect as well as variation of temperature, and it will generally be impossible at any particular time and place to know for certain what the refraction really amounts to, especially if the course of the ray is long.

(2) It is scarcely correct to speak of the irregular distribution of temperature near the ground as being due to conduction. True conduction in the air is quite insensible compared with diffusion by eddies and the general instability of flow.

A. MALLOCK.

The X-ray Structure of Potassium Cyanide.

WRITING in the current number of the Proceedings of the Royal Society, Prof. A. O. Rankine concludes from determinations of the viscosity of cyanogen gas that the cyanogen molecule "behaves in collision like a hard body formed by two overlapping hard spheres, each of which has the kinetic properties of a nitrogen molecule." He gives as the distance between the centres of these overlapping spheres $2{\cdot}3\times10^{-8}$ cm. Prof. Rankine also remarks: "It is significant that the crystals of potassium cyanide and those of the potassium halides are usually stated to be iso-

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morphous, and that, in addition, we find that KBr and KCN have nearly identical molecular volumes—43·1 and 42·8 respectively. Thus if CN replaces Br there is no appreciable change in volume, and we may conclude, tentatively, that the cyanogen radicle and the bromine atom have the same size."

Acting on the suggestion of Prof. W. L. Bragg, the writer has made X-ray examinations of small single crystals of KCN by the ordinary spectrometer method, and of powdered crystals by the modification of the method recently described by Sir W. H. Bragg before the Physical Society of London. The results of this preliminary investigation indicate that the underlying structure of KCN is similar to that of KBr, the cyanogen radicle replacing the bromine atom. For instance, the strongest reflection is that given by the [100] face at a glancing angle of 6° 15′. This corresponds to a distance of 3·27 Å. between the planes, and the calculated mass associated with the unit cube the edge of which is of this length is one-half of the mass of the KCN molecule; this is a characteristic of the face-centred lattice. The first-, second-, and third-order reflections from the [100] face have intensities which decrease in the normal way, although at a greater rate than is usually the case; the first-order reflection given by the [111] face at a glancing angle of 5° 40′ is relatively small, while the second-order reflection at 11° 30′ is normal, as is also the first-order reflection from the [110] face. These spectra correspond to those given by NaCl, where the unit of the structure consists of a cube with atoms of one kind arranged at the corners and face centres, and atoms of the other kind at the mid-points of the edges and at the cube centre.

The data obtained, while being sufficient to fix the position of the CN radicle as a whole with respect to the potassium atom, afford practically no evidence as to the disposition of the carbon and nitrogen atoms towards each other. So far as the lower orders of spectra are concerned, the CN radicle behaves as a single unit, whose power of diffracting X-rays differs from that of the potassium atom. The edge of the unit cube in the KCN crystal is 6·54 Å. Taking 4·15 Å. as the diameter of the potassium atom (Prof. W. L. Bragg, *Phil. Mag.*, August, 1920), this leaves 2·39 Å. as the width of the space, measured along the cube edge, to be filled by the CN radicle. The diameter of the bromine atom is 2·38 Å.

The results of the investigation will be published in detail elsewhere. P. A. Cooper.

Manchester University, July 28.

An Ornithological Problem.

Staying this last week-end with a friend at Overstrand, I was much puzzled on the morning of August 6 by a strange bird which I first saw sitting on some low iron gates at the end of the lawn, when I took it for some kind of hawk. It then settled for a time on a croquet-hoop, and ultimately flew away, when its long wings and tail and smooth flight again suggested a hawk. My host, who had seen it before, thought it might be a cuckoo, and this, when a little later we saw it again in flight, seemed a probable solution.

We did not see the bird again until the evening of August 7, when during a heavy shower it appeared on the lawn and perched on a croquet-hoop close to the house. I then saw that its plumage was not grey-blue, like the adult cuckoo, but a rich mottled brown, and I began to think that it might be a nightjar, though its beak seemed a little too long and its appearance in a beautifully trim garden on the edge of the sea, in the daytime, out of character. Moreover, both on gate and croquet-hoop it sat crosswise, not lengthwise as the nightjar does on a branch. It also occasionally hopped, somewhat clumsily, across the lawn and regaled itself with a worm like any thrush.

On my return to town it was suggested to me that the bird might be a young cuckoo. It so happened that I had never seen one, and so was not aware how different the plumage is from that of the adult bird. After consulting the authorities, however, such as Dresser and Lilford, I am satisfied that this is the right solution, for the mottled brown plumage is quite in order, and the beak and the length of wings and tail are clearly more those of a cuckoo than of a nightjar. Moreover, we are expressly told that the cuckoo when on the ground hops in an ungainly fashion, whereas it is doubtful whether a nightjar with its peculiarly constructed feet could hop at all. The cuckoo, like the nightjar, is normally insectivorous, but this bird might have been brought up by a thrush and imitated its foster-parent's method of dealing with worms on a lawn. Presumably the young cuckoo is not ready for its long flight across sea so soon as the adult bird, of whom we read, "In August, go he must." George A. Macmillan.

August 9.

Uniform Motion in the Æther.

It seems to be fairly generally conceded that uniform motion relative to the æther is, in principle, undetectable by optical devices. Poincaré, for instance, who did not entirely accept the positions of relativity, stated as his opinion that "optical phenomena only depend on the relative motions of the bodies concerned, and this not to quantities of the order of the square or cube of the aberration, *but rigorously*."

A very simple consideration, however, shows that such a view is untenable. Thus, if we have a vertical mirror, with a horizontal motion in its own plane relative to the earth, and if a horizontal beam strikes it, the angles of incidence and reflection must, as measured from the moving mirror, be equal, for otherwise the measured discrepancy would determine the earth's motion.

Owing to the aberration, however, these apparently equal angles are not, in general, truly equal, nor are they equal as measured from the earth. It is only when the direction of the earth's motion is in the direction of the horizontal axis of the mirror that they will be equal when so measured.

This determines the direction of the earth's motion, and from the discrepancy in the other cases the magnitude of the velocity could be found.

An effect of the FitzGerald-Lorentz contraction would be to distort angles, so that, for example, a measured right angle, the bisector of which was in the direction of the earth's motion, would be greater than a true right angle; but this would not be compensatory in the case of the mirrors, and would itself, in another connection, serve to determine the earth's motion.

In fact, angular measurements of the stars would suffer discrepancies of a maximum of about 0·001″, in opposite directions, at intervals of three months, owing to the earth's motion in its orbit, and any added motion would probably be detected if an accuracy of 0·001″ in the measurement of large angular distances could be obtained.

As another example of a different kind, the simple immersion in still or moving water of the Michelson-Morley apparatus ought, theoretically, to give a positive result, since the water moves relatively to the æther, and Fizeau's law indicates that the velocity of light in moving water is not the same in all directions; while if the water moves relatively to the apparatus, this velocity is independent of the particular contractions of the latter. E. H. Synge.

Dublin.

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